THE ASTRONOMICAL JOURNAL, 121:2185–2188, 2001 April

A 2MASS L DWARF COMPANION TO THE NEARBY K DWARF GJ 1048

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Received 2000 April 19; accepted 2000 December 20

ABSTRACT

We report the discovery of a probable L1 companion to the nearby K2 dwarf GJ 1048 using the Two Micron All-Sky Survey (2MASS). This source, 2MASSI J0235599−233120, or GJ 1048B, has 2MASS near-infrared colors and absolute magnitudes consistent with an early L dwarf companion with a projected separation of 250 AU. The L1 spectral type is confirmed by far-red optical and low-resolution IR spectroscopy. We present evidence that GJ 1048 is a young ($\lesssim 1$ Gyr) system, and that GJ 1048B may be a high-mass brown dwarf below the hydrogen burning limit. Additional studies of the GJ 1048 system will help constrain the characteristics of L dwarfs as a function of age and mass.

Key words: binaries: general — solar neighborhood — stars: low-mass, brown dwarfs

1. INTRODUCTION

Brown dwarfs are very low mass dwarfs that are unable to maintain a stable luminosity by hydrogen fusion. Analysis of radial velocity surveys has identified a "brown dwarf desert"—although stellar and planetary companions to FGKM main-sequence stars are relatively common, less than 1% of such stars have companions in the range 0.005–0.08 $M_{\odot}$ within 3 AU (Mazeh et al. 1992; Marcy & Butler 2000). Although brown dwarfs are rare as short-period companions to more massive stars, they are quite common in the field. The Deep Near-Infrared Survey, Two Micron All-Sky Survey (2MASS), and Sloan Digital Sky Surveys have been used to identify numerous *isolated* brown dwarfs (Delfosse et al. 1999; Kirkpatrick et al. 1999, 2000; Strauss et al. 1999; Burgasser et al. 1999) belonging to both the new cool L and yet cooler T (methane) spectral classes. A first attempt at modeling indicates that these discoveries imply that isolated substellar objects likely have a space density comparable to that of hydrogen burning stars (Reid et al. 1999). This discrepancy between the frequency of short-period brown dwarf secondaries and isolated field brown dwarfs raises questions about star formation and binary formation. It is not yet known, however, if the brown dwarf desert extends to wide separations. Mazeh et al. (1992) have already noted that short-period ($P < 3000$ days) systems with G dwarf primaries have a mass ratio distribution that is flat or even favors high mass ratios, while wider systems favor low-mass (small mass ratio) systems.

2MASS offers the opportunity to address the frequency of brown dwarf companions for separations sufficiently large that the low-luminosity companions can be resolved. The feasibility of such a project has already been demonstrated by the discovery of two M dwarf stellar companions to G dwarfs (Gizis et al. 2000a, 2000b), two L brown dwarf companions to G dwarfs (Kirkpatrick et al. 2000), and one T brown dwarf companion to a K+M+M triple system (Burgasser et al. 2000), as well as by our recovery of the L brown dwarf companion to the M dwarf G196-3 (Rebolo et al. 1998)—all by searches aimed at identifying *isolated* dwarfs. A definitive measurement of the stellar and brown dwarf companion frequency requires careful statistical analysis accounting for the ages, distances, and other characteristics of the systems searched, but in the meantime analysis of any L dwarf in a multiple system is important because measurements of the primary's trigonometric parallax, composition, and age constrain the L dwarf's properties.

We report the identification and confirmation of an L dwarf companion to the nearby K2 dwarf GJ 1048 (HD 16270). Our measurements of the L dwarf are described in § 2 and the age and masses of the GJ 1048 system are discussed in § 3.

2. DATA

We used the 2MASS Working Database to search for sources without optical counterparts within 60″ of a star in the preliminary Third Catalogue of Nearby Stars (Gliese & Jahreiss 1991). We then examined each image to confirm that the putative companion was not an artifact. We have not yet followed up all the candidates identified by the search, so no statistics can be computed. However, we noted that one candidate near the K2 dwarf GJ 1048 had $J - K_s = 1.354 \pm 0.140$ and $K_s = 12.315 \pm 0.077$, consistent with an early L dwarf at the distance of GJ 1048. This object is named 2MASSI J0235599−233120 based on its position and inclusion in the 2MASS Second Incremental Release Point Source Catalog,[2] but henceforth we refer to it as GJ 1048B; the primary, whose catalog entry is 2MASSI 0236007−233116, we refer to as GJ 1048A. GJ 1048B is 3″.75 south and 11″.34 west of the primary, implying a physical separation on the sky of 250 AU.

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[2] See Cutri, R. N., et al., Explanatory Supplement to the 2MASS Second Incremental Data Release at http://www.ipac.caltech.edu/2mass/releases/second/index.html.

We obtained low-resolution J- and K-band spectra on 1999 November 27 using the near-infrared cryogenic spectrograph (CRSP) on the Kitt Peak Mayall 4 m telescope. Details of the observing procedure and other L dwarfs observed will be given in Gizis et al. (2001). A low-resolution spectrum covering 0.9–2.4 μm was also obtained using the CorMASS infrared spectrograph (Wilson et al. 2001) on the Palomar 60 inch (1.5 m) telescope. The two spectra obtained with different instruments and reduction procedures are in good agreement with each other. Before a far-red spectrum of GJ 1048B was obtained, a near-infrared spectral type was estimated. Available diagnostics include the slope of the J-band spectrum, the presence of FeH and K I lines in the J band (McLean et al. 2000), and the strength of H_2O, H_2, and CO absorption at the K band (Tokunaga & Kobayashi 1999). Based on the comparison of these features with those of dwarfs classified on the Kirkpatrick et al. (1999) system, an early L spectral type was estimated. Figure 1 shows the CorMASS spectra of GJ 1048B and the L1 dwarf 2MASSW J0208183+254253 (Kirkpatrick et al. 2000). Figure 2 compares CRSP spectra of GJ 1048B and the L2 dwarf 2MASSW J0015447+351603 (Kirkpatrick et al. 2000).

On 2000 August 23 we obtained a Keck Low-Resolution Imaging Spectrometer (LRIS) (Oke et al. 1995) spectrum of GJ 1048B (Fig. 3). The setup corresponded to that used in Kirkpatrick et al. (1999). The Kirkpatrick et al. (1999) spectral type is L1, and there is no detectable Hα or lithium. The $J-K_s$ color is consistent with this spectral type (Kirkpatrick et al. 2000, their Table 5).

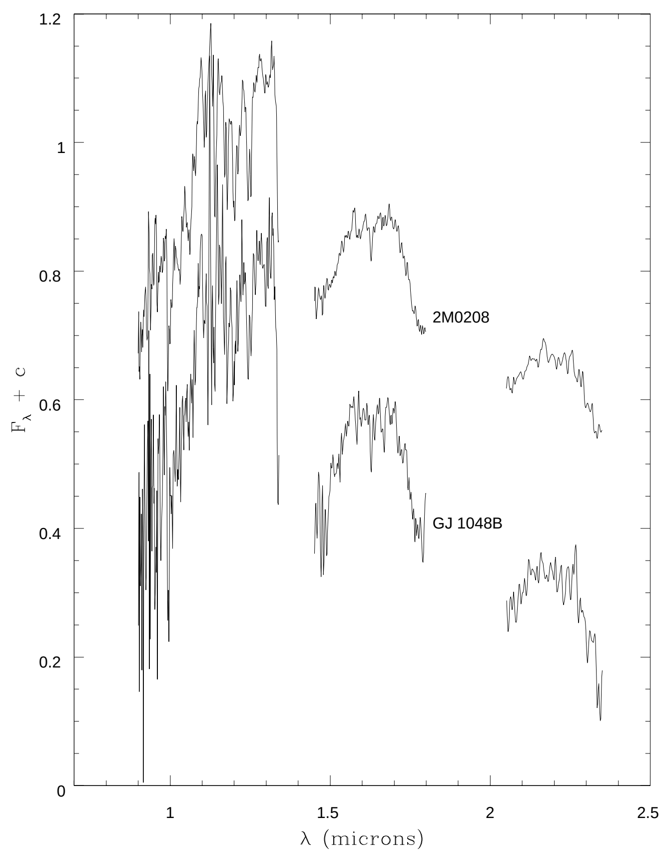

FIG. 1.—CorMASS near-infrared spectra of GJ 1048B and 2M0208, a known L1 dwarf. 2M0208 has been normalized to agree with GJ 1048B and shifted upward by 0.3. The relative fluxes between the J-, H-, and K-band regions may have small offsets.

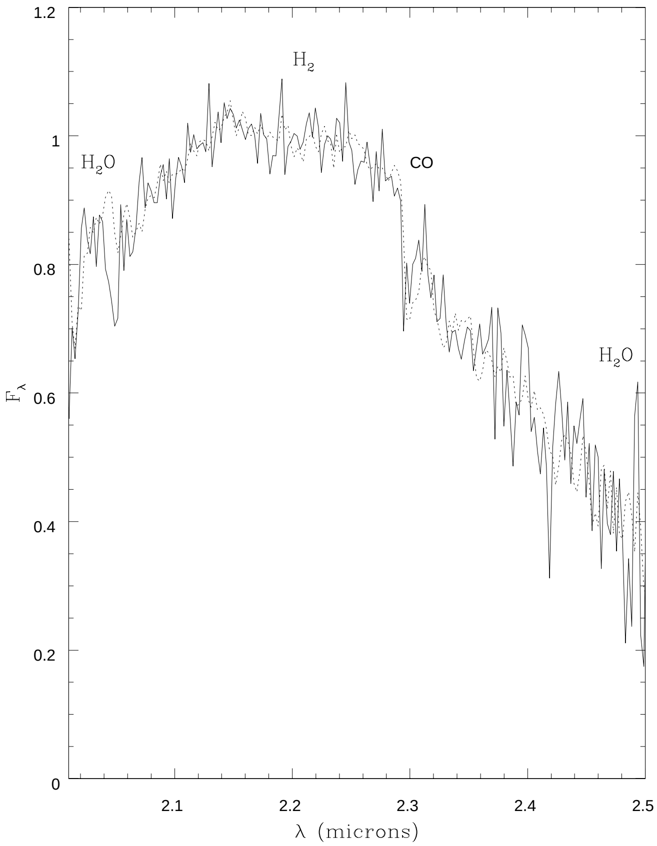

FIG. 2.—Near-infrared K-band spectrum of GJ 1048B (*solid line*) compared to that of L2 dwarf 2MASSW J0015447+351603 (*dotted line*). The two spectra have been renormalized to unity over the range 2.14–2.26 μm.

The accurate *Hipparcos* parallax of 47.04 ± 1.04 mas (Perryman et al. 1997) implies $M_K = 10.677 \pm 0.09$. Kirkpatrick et al. (2000) have used the latest parallax data to derive an L dwarf spectral type-distance relationship. For a spectral type L1, the relation gives $M_K = 10.60$ (the observed scatter in the relation is $\lesssim 0.5$ mag), which is in excellent agreement. The consistency of the absolute magnitude with the color and spectral type supports our interpretation that the L dwarf is a companion to the K dwarf.

Given the uncertainties in the relation between spectral type and temperature (Kirkpatrick et al. 2000; Basri et al.

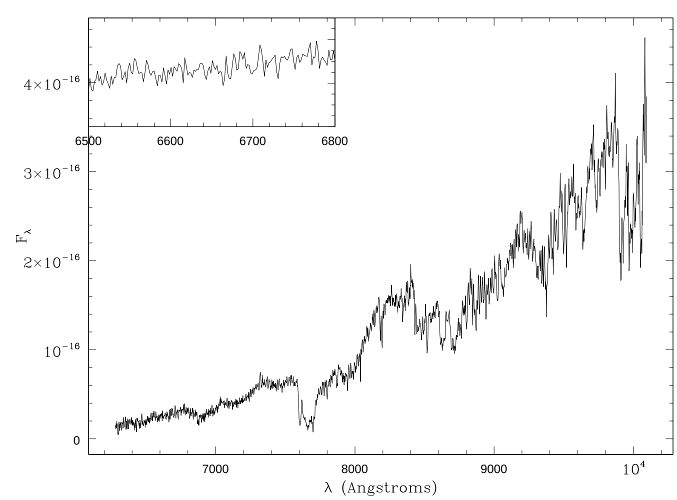

FIG. 3.—Keck LRIS spectrum of GJ 1048B. There is no evidence of lithium absorption or Hα emission.

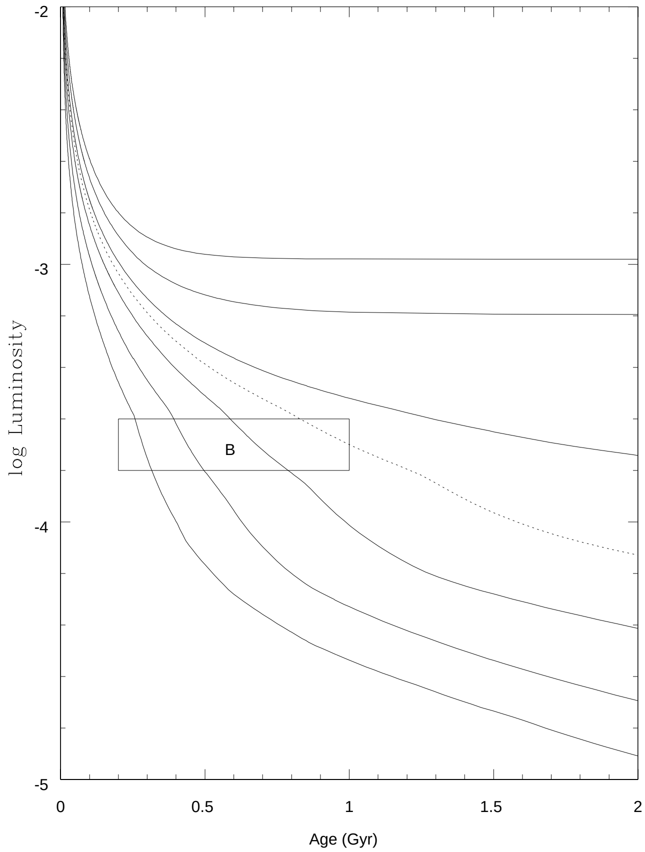

FIG. 4.—Burrows et al. (1993, 1997) models of the luminosity evolution of stars and brown dwarfs. From left to right, the lines represent 0.05, 0.06, 0.07, 0.076 (*dotted*), 0.08, 0.09, and 0.10 $M_{\odot}$ models. The B marks our best estimate of the age and luminosity of GJ 1048B, and the box shows our estimate of the probable range of these parameters.

2000; Leggett et al. 2001), GJ 1048B is likely to lie in the range 1900–2200 K. Judging by the results of Tinney, Mould, & Reid (1993), Jones et al. (1994), and Leggett et al. (2001) for late M and L dwarfs, a bolometric correction of $BC_K = 3.3 \pm 0.2$ is appropriate, implying $\log L/L_{\odot} = -3.7 \pm 0.1$.

The proper motion of GJ 1048A is only 0".0855 yr^{-1}, so confirmation that GJ 1048B has the same motion may be possible with careful observations within a few years, but it is not possible for 2MASS—it will be 4 years until the system moves by 2 σ (counting only the first epoch uncertainty). However, we can assess the probability that an unassociated field L dwarf will be within 20" of a cataloged nearby star. The surface density on the sky of 2MASS L dwarfs to $K_s = 14.7$ is 0.05 $(\mathrm{deg}^2)^{-1}$ (Kirkpatrick et al. 1999), so the probability that a 2MASS L Dwarf lies within 15" of any of the $\sim$4000 cataloged nearby stars is only 0.01. However, 80% of the Kirkpatrick et al. (1999) L dwarfs lie at distances greater than 30 pc, so the probability that an L dwarf with a consistent distance estimate will be found is only $\sim$0.002 over the entire sky. It is therefore highly likely that GJ 1048B is associated with the nearby K dwarf.

3. DISCUSSION

We may take advantage of our knowledge of GJ 1048A to constrain the nature of GJ 1048B. GJ 1048A has estimated metallicity of $[\mathrm{Fe/H}] \approx -0.07$, a K2 dwarf spectral type, and $B-V = 1.07$ (Zakhozhaj & Shaparenko 1996; Perryman et al. 1997). Using the observed V, J, and K absolute magnitudes with mass-absolute magnitude relationships based on binary star orbits (Henry & McCarthy 1993), we find that GJ 1048A has a mass of $\sim 0.77 \, M_{\odot}$.

GJ 1048A is detected as a *ROSAT* X-ray source with $\log L_X = 28.2$ (Hünsch et al. 1999). Since X-ray emission is linked to age, we may estimate the age of the GJ 1048 system. Barbera et al. (1993) have analyzed the X-ray coronae of field K dwarfs as a function of kinematic age. GJ 1048A's X-ray luminosity is typical for a "young disk" star and brighter than 95% of "old disk" stars. More definite ages may be attached by using deep *ROSAT* pointings of open clusters. GJ 1048A's corona is less luminous than all dK stars in the Pleiades (age $\sim 10^8$ yr) with similar $B-V$ colors (Stauffer et al. 1994), so it is likely older than that cluster. GJ 1048A's corona is comparable to the median X-ray luminosity observed for single Hyades (age $\sim 6 \times 10^8$ yr) K dwarfs (Pye et al. 1994). The uncertainty in this estimate is necessarily large—not only is there a range of X-ray luminosities in any given cluster, but the similar-age Praesepe and Ursa Major clusters show systematically weaker X-ray emission than do the Hyades (Randich & Schmitt 1995). There are no available calibrating clusters near 1 Gyr, so we cannot set a definite upper limit to the age. An uncertainty of a factor of 2 seems appropriate. Our best estimate is that the GJ 1048 system has an age of $\sim 6 \times 10^8$ yr, though it is possibly as old as $\sim 10^9$ yr.

We note that if GJ 1048A is actually a short-period binary, its activity will be enhanced and it may be much older. According to the SIMBAD database, no radial velocity studies of GJ 1048A have been conducted. The young age, however, is supported by the kinematics of the star. The *Hipparcos* proper motion and parallax (Perryman et al. 1997) implies $v_{\mathrm{tan}} = 8.62$ km s^{-1}, which is characteristic of a very young star.

What does this age imply for the nature of GJ 1048B? Models that incorporate dust (Burrows et al. 1993) indicate that the hydrogen burning limit extends down to masses of 0.076 $M_{\odot}$, $T_{\mathrm{eff}} \approx 1750$ K, and $\log L/L_{\odot} \approx -4.2$. Without any age information, GJ 1048B is certainly consistent with being a hydrogen burning star. In the Burrows et al. (1993, 1997) and Baraffe et al. (1998) models, however, it requires 10^9 yr for a star at the hydrogen burning limit to cool to the luminosity of GJ 1048B. (Since the luminosity is better determined than the temperature, we use it for comparison with the models.) Given our age estimates, it is likely that GJ 1048B is a high-mass brown dwarf, but the data are also consistent with a star at the hydrogen burning limit at an age of 1 Gyr. The younger the system, the more likely that GJ 1048B is a brown dwarf (Fig. 4). The absence of lithium is not surprising, since it only requires $\sim 3 \times 10^8$ yr for a 0.055 $M_{\odot}$ model (the lithium burning limit) to fade to the observed luminosity. Given the mass range 0.055–0.075 $M_{\odot}$, the binary mass ratio q is $\approx$0.07–0.10. The absence of Hα emission in the L dwarf is also not surprising, because young L dwarfs tend to not show Hα (Gizis et al. 2000b).

Additional observations of this system are needed to improve our knowledge of brown dwarfs. Measurement of the primary's radial velocity, rotation period, rotation velocity, and chromospheric activity might improve the age estimate. A search for a closer companion, which could influence the activity level of the primary, is also needed.

4. SUMMARY

We have detected a probable L1 dwarf companion to the K dwarf GJ 1048A. Given the X-ray emission and low velocity of the primary, GJ 1048B is likely to be below the hydrogen burning limit; if a true star, it is within 0.005 $M_{\odot}$ of the limit. Studies of the primary may be able to further constrain the age and status of the system. As an object very near the hydrogen burning limit, GJ 1048B should serve as an important object for further study.

We thank the staffs of Kitt Peak and Palomar observatories for their assistance in these observations and the many people who have worked on making 2MASS a reality. CorMASS was made possible by the work of Mike Skrutskie, Jim Houck, J. D. Smith, Michael Colonno, Alan Enos, and Chuck Henderson. Adam Burrows, Gilles Chabrier, and Isabelle Baraffe were kind enough to make their models available in electronic form. J. E. G. and J. D. K. acknowledge the support of the Jet Propulsion Laboratory, California Institute of Technology, which is operated under contract with NASA. This work was funded in part by NASA grant AST 93-17456 and JPL contract 960847. J. C. W. acknowledges support by NASA grant NAG 5-4376. This publication makes use of data products from 2MASS, which is a joint project of the University of Massachusetts and IPAC/Caltech, funded by NASA and NSF. This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France.

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